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Distribution of forest birds in the Andaman islands: importance of key habitats

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Abstract

Aim The aim of this study was to assess the influence of island area, distance to source pool, latitude, habitat diversity and habitat type on species richness of forest birds in the Andaman islands.

Location The Andaman islands (India) in the Bay of Bengal.

Methods The distributions of 47 species of forest birds were surveyed on 45 islands in the Andaman islands across a latitudinal gradient. The size of the island and distance to the nearest large island were assessed on a satellite image of 1 : 250,000 scale. The number and types of habitats and the species richness of birds on each island were recorded during a field survey. The effects of the variables measured on the species richness of forest birds were assessed using regression analyses. The best fit models were selected for interpretation of the results. Separate analyses were conducted with selected islands to eliminate the effects of latitude and to control the effects of area and habitat diversity.

Results The number of species of forest birds was strongly influenced by island area and habitat diversity. However the key determinant of species richness was habitat type, particularly the presence of wet forests. Wet forests, either semi-evergreen or evergreen tropical forests are more common towards the southern islands and are usually restricted to larger islands.

Main conclusions Area, habitat diversity and the presence of wet forests on islands significantly influenced species richness of forest birds. The wet forests maintain the biodiversity of the Andamans and should be regarded as a 'keystone habitat'. This is probably because wet forests are species rich and also because the Andaman biota has affinities with that of the Malay peninsula where wet forests predominate. Therefore biogeographical history probably plays an important role in influencing biodiversity at a regional scale.

Keywords
Andaman islands, conservation, forest birds, India, island biogeography, keystone habitat.

INTRODUCTION

The question of whether area *per se* or habitat diversity is more important in influencing species richness on islands has been the subject of debate (Williams, 1964; MacArthur & Wilson, 1967; Simberloff, 1976; Connor & McCoy, 1979; Gilbert, 1980; Boecklen & Gotelli, 1984; Boecklen, 1986; Kohn & Walsh, 1994). The support for the area *per se* hypothesis comes from Simberloff's (1976) experimental study of defaunated mangrove islands off the coast of Florida. Other studies have emphasized the effect of habitat diversity on species richness (Williams, 1964; Boecklen, 1986; Kohn & Walsh, 1994). Habitat diversity was found to significantly influence species richness when area was factored out (Boecklen, 1986). This debate has influenced conservation practice as well, where the relative merits of

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large vs. small reserves, are contested based on the interpretations of island biogeographic theory (Wilson & Willis, 1975; Simberloff & Abele, 1976; Higgs, 1981; Boecklen & Gotelli, 1984).

However, in most cases, the effects of area and habitat diversity are inter-related (Connor & McCoy, 1979; Gilbert, 1980; Boecklen & Gotelli, 1984), and often influence each other directly and indirectly (Kohn & Walsh, 1994). Recent work has shown that habitat diversity and the availability of particular habitat types might be important in determining the species richness of Aegean land snails (Welter-Schultes & Williams, 1999). The occurrence of wet forests on islands significantly influenced butterfly distributions in the Andaman islands (Devy *et al.*, 1998).

The Andaman islands which lie off the coast of S. E. Asia in the Bay of Bengal provide a natural laboratory for testing the effects of area, habitat diversity and habitat type on species richness. First, there is a latitudinal gradient which influences the climate and consequently the vegetation (Ellis, 1989; Davidar *et al.*, 1995). The presence of well defined and easily recognizable forest types (Champion & Seth, 1968) make identification of habitats and habitat analyses possible. The habitat use patterns and the biogeographical history of birds are also known (Ripley & Beehler, 1989; Yoganand & Davidar, 2000), making inferences easier than for other taxa.

In the Andamans, the relationship between species, area and habitat related factors can be analysed by controlling both area and levels of habitat diversity and habitat type. The relationship between species and habitat diversity can be analysed by looking at islands of similar sizes with different levels of habitat diversity. Similarly the effect of area can be determined by looking at islands of different sizes with similar levels of habitat diversity. The differential impact of each variable can be analysed by using multiple regression analysis.

We conducted a study of the insular biogeography of forest birds in the Andaman islands and looked at the effects of area and habitat related factors on species richness of forest birds.

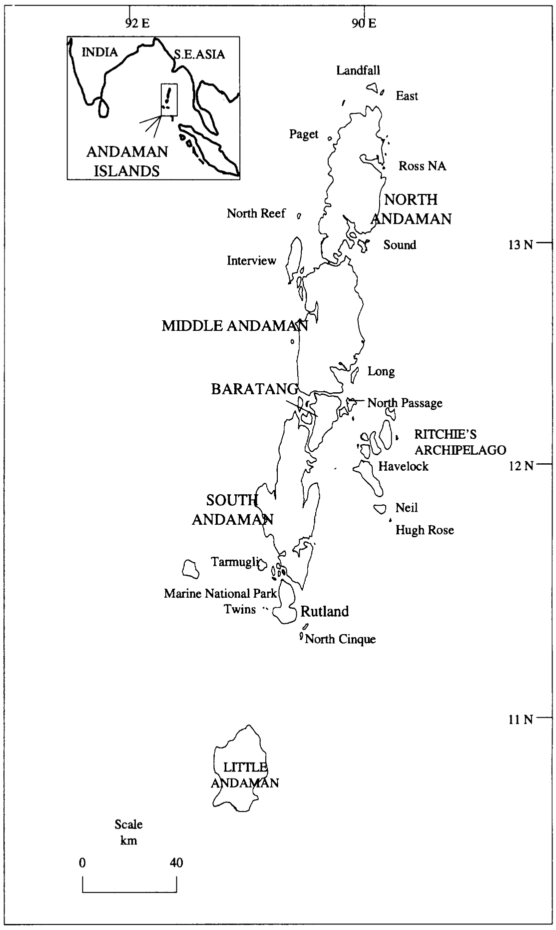

Figure 1 Map of the Andaman islands.

STUDY AREA

The Andaman islands lie between 10°30′ – 13°41′ N and 92°12′ – 93°57′ E, off the coast of S. E. Asia in the Bay of Bengal about 571 km from the Malay peninsula and 1330 km from southern India (Fig. 1, Ripley & Beehler, 1989). The northernmost islands are about 285 km from Myanmar and the southernmost is the Little Andaman island. The climate is tropical and oceanic with rainfall from both the SW and NE monsoon winds. The average annual rainfall is 3000 mm (Anonymous, 1989), increasing from the northern to the southern islands (Ellis, 1989). This results in a north–south vegetational gradient with predominantly drier forests in the northern islands and wetter forests in the southern islands (Davidar *et al.*, 1995).

Most of the land area of the Andamans is comprised of four large and contiguous islands, the North Andaman island, the Middle Andaman island, Baratang and the South Andaman island. Rutland, a large island lies close to the southern tip of the South Andaman island. The Little Andamans, another large island is 67 km south, and the southernmost in the Andaman group. The Little Andaman island is separated from the Nicobars further south by the 140 km wide '10° channel'.

Ripley & Beehler (1989) listed 104 species of breeding birds on the Andaman and Nicobars. This includes 17 endemic species (T. Inskipp, personal communication), and 86 endemic races. Their affinities are predominantly with Myanmar and the Malay peninsula, 81 of the species also breed in south-western Myanmar and 75 in the Malay peninsula.

MATERIALS AND METHODS

Bird survey

Bird lists for each island were compiled on 1 km long transects laid through each forest type on a larger island or across all forest types on a smaller island. These transects were walked in the mornings starting at dawn. The number of transects was related to the size of the habitat. All birds seen and heard were recorded and identified using Ali & Ripley (1987) and King *et al.* (1975) to get a measure of species richness and relative abundance. Each transect was walked several times until the species accumulation curve reached an asymptote.

Rarity and commonness of forest birds were assessed by their distribution and abundance. To study their distribution, each species, was ranked in ascending order according to the number of islands on which recorded. The total number of sightings per species in the surveys were ranked in ascending order in order to assess abundance. An index was developed using distribution and abundance to identify rare and common species (Gaston, 1994; see Davidar *et al.*, 1996 for details).

All the 104 species of breeding birds were recorded in the survey, however, 47 were identified as predominantly forest dwelling and included in the analysis (Appendix 1). Species with restricted distributions such as the Narcondam Hornbill (*Aceros narcondami*), those that were difficult to sample, nocturnal species and those dependent on water bodies were excluded. Only one species, the Pied Cuckoo Shrike (*Coracina nigra*), was missed in this survey. This species could be very rare, or be restricted to secondary habitats (Ali & Ripley, 1987).

Islands sampled

Forty-five islands in the Andaman group were surveyed during the dry seasons, from February to May 1992, 1993 and February of 1994 (Appendix 2). This survey covered the large island masses from the North to the Little Andaman island and islands in the associated archipelagoes (Fig. 1, Davidar *et al.*, 1995).

The South Andamans and the Labyrinth archipelago were surveyed from February to May 1992. Baratang, the Ritchie's archipelago and seven islands off the North Andamans were surveyed from February to May 1993, and the North Andaman island and 11 associated islands were surveyed in February 1994. The Little Andaman island was surveyed in 1992 and 1994 (Fig. 1).

The area of each island and the distance to the closest large island were calculated from measurements on satellite images of 1 : 250,000 scale. The outline of each island was traced on a mm^2 tracing sheet and the area was calculated by counting the squares covered by the tracing and the distances were measured to the nearest mm. These measurements were later converted to km^2 for area and km for distance. The effect of latitude on species richness was analysed by recording the latitude of each island on a map. The centre of large islands was taken as the representative latitudinal position for that island. The degree decimal coordinates were used in all calculations.

Habitat distribution analyses

Forest was taken to be synonymous with habitat and all the forest types on an island were initially recorded in a preliminary survey. The different types of forest encountered were identified with the help of Champion & Seth (1968) and were classified into three groups: littoral forests, deciduous forests and wet forests (evergreen and semi-evergreen). Littoral and deciduous forests were more open and drier than the wet forests. The habitat description was carried out during the dry season when the different forest types are easier to identify as the deciduous species lose their leaves. Further details are given in Davidar *et al.* (1995). A habitat analysis was conducted across all the island groups and island sizes.

The distribution of the forest types within the different island groups (North, Middle and South Andamans), and on islands of different sizes were analysed. Islands were grouped into size classes of < 0.1, 0.1–0.99, 1–9.99 and 10–15 km^2. The number and percentage of islands in each size class with littoral, deciduous and wet forests were estimated.

Island biogeography

All islands

The effects of island size, distance from the nearest large island and habitat diversity on species richness (Sokal & Rohlf, 1981) were analysed by using regression analyses. Untransformed and log-transformed variables were used in the regressions to obtain the best fit model. The model giving the highest R^2 and which linearized the regression was taken as the best fit model (Connor & McCoy, 1979).

Simple regressions were conducted separately on the effects of area, distance and habitat diversity on species richness. For the distance analysis, the large islands which are contiguous with each other were excluded, as 'distance from the nearest large island' was used instead of the mainland as the source pool for species. Latitude was not considered in this analysis as the large islands fall within a range of latitudes. A multiple regression analysis was then conducted in order to understand the relative contributions of each variable on species richness.

Species–area relationships on smaller islands

Regression analysis between the independent variables and species richness were conducted using a subset of 37 smaller islands < 15 km^2 in area. This is because the levels of species richness and habitat diversity saturated on the larger islands, potentially obscuring significant relationships.

Area and habitat diversity

The relative importance of area and habitat diversity were inferred from the results of the above regressions, as well as by controlling to attain the effects of either by using a subset of the data.

To investigate the effects of area on species richness without the confounding effects of habitat diversity, a subset of islands were selected in order to standardize the levels of habitat diversity. For example, the number of habitat types on an island were used to denote the habitat diversity level of that island. For instance, islands with two habitat types were assigned a code of 2, and those with three habitat types were assigned a code of 3 (Appendix 1). A simple regression analysis between area and species richness on 10 islands of different sizes with habitat diversity levels of 2 and 3 were conducted.

To look at the effects of habitat diversity without the confounding effects of area, seven islands of similar sizes with areas ranging between 11 and 15 km^2 were selected, and a regression analysis between habitat diversity and species richness was performed.

Effects of habitat type

To look at the effects of habitat type on species richness, a subset of 16 islands between 1 and 15 km^2 were selected. Of the 16 islands, eight had wet forests and eight did not. Regression analyses between area and species richness, were performed separately for islands with and for islands without wet forests.

The contribution of wet forests to species richness was further analysed by looking at islands with and without wet forests in habitat diversity classes 2 (islands with two forest types) and 3 (islands with three forest types). Islands in these two different habitat diversity classes were separately compared for differences in species richness using a Wilcoxon test (Siegel & Castellan, 1989).

RESULTS

Habitat description

The littoral forest was the most common occurring in 98% of all the islands. Deciduous forests were recorded on 64% of the islands surveyed and wet forests (evergreen and semi-evergreen) on 45% of the islands (Table 1).

The proportion of islands with wet forests changes significantly with latitude for islands between the size classes 1–15 km^2. Wet forests are more common in the southern than on the northern islands (X^2 13.33, d.f. = 2, $P = 0.001$, Table 2).

Determinants of species richness

Statistical models

For the whole of the Andaman islands, the relationship between species and area was analysed using the log species/log area and species/log area models. Both gave significant results although the species/log area regression, called the exponential model, linearized the equation and was therefore considered the best fit model (Fig. 2, Table 3). Distance did not influence species richness (Table 3).

There was a significant relationship between species and area within each island group (Table 3). These island groups fall within particular latitudinal gradients. The power function model was used for the analyses as it facilitated comparison amongst the three island groups and gave better R^2 values than the exponential model. However the slope was curvilinear for North Andamans, as the mean number of species was lower when compared with islands of similar areas in the Middle and South Andamans (Table 4, Appendix 2).

Table 1 Distribution of forest types amongst the different island groups

Island group	Total number of islands	Forest types (number of islands, %)		
		Littoral	Deciduous	Wet
North Andaman	17	17 (100)	12 (71)	2 (12)
Middle Andaman	14	14 (100)	11 (79)	10 (71)
South Andaman	13	12 (92)	5 (38)	8 (62)
Total	44	43 (98)	28 (64)	20 (45)

Table 2 Latitudinal intervals and the distribution of islands with and without wet forests for islands between 1 and 15 km^2 (X^2 13.33, d.f. = 2, $P = 0.001$)

Latitudinal interval (°)	Islands with wet forests	Islands without wet forests
13–14	0	4
12–13	4	3
11–12	4	1

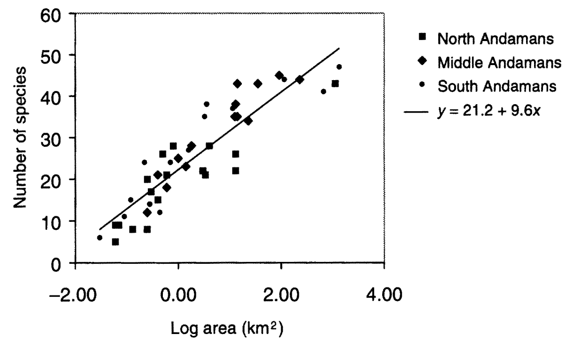

Figure 2 Species–area relationship of forest birds on 45 islands in the Andamans. Species total = 21.19 + 9.56 (log area).

The mean numbers of species were similar for all island groups in the small island size classes (< 0.1 km^2), whereas it was lower for the North Andaman group as compared with the Middle and South Andaman groups for the larger size classes (0.1–0.99 and 10–15 km^2, Table 4).

There was a significant relationship between species and log area, when islands < 15 km^2 were compared (Table 3).

Area, habitat diversity and habitat type

Habitat diversity was positively correlated with species richness for the whole data set and for smaller islands as well (Table 3). There was a significant relationship between log species and log area within the 10 islands with habitat diversity levels 2 and 3 (level 2: log species = 1.27 + 0.25 log area, $R^2 = 0.58$; and level 3: log species = 0.705 + 0.28 log area, $R^2 = 0.82$, d.f. = 9, $P < 0001$).

Table 3 Regression models giving estimates of intercept, slope and R^2

Variables	n	Intercept	Slope ± SE	R^2	P-value	Regression model
Species/log area	45	21.19	9.561 ± 0.72	0.806	< 0.0001	Linear
Species/habitat	45	1.92	8.24 ± 0.79	0.72	< 0.0001	Linear
Species/distance	39	26.08	0.244 ± 0.172	0.05	n.s.	Linear
Habitat/log area	45	2.44	0.89 ± 0.09	0.58	< 0.0001	Linear
Species/log area/habitat	45	13.05	Area = 6.59 ± 1.12	0.81	< 0.0001 (t = 5.88)	Multiple
			Habitat = 3.32 ± 1.02	0.65	< 0.002 (t = 3.25)	
Island groups						
Log species/log area						
North Andamans	17	1.35	$0.21x$ ± 0.042	0.77	< 0.0001	Polynomial
			$0.18x^2$ ± 0.059			
Middle Andamans	14	1.24	0.23 ± 0.052	0.87	< 0.0001	Linear
South Andamans	13	1.36	0.29 ± 0.47	0.81	< 0.0001	Linear
Islands < 15 km^2						
Species/log area	37	0.15	10.87 ± 1.22	0.69	< 0.0001	Linear
Species/habitat	37	3.85	7.198 ± 1.42	0.42	< 0.0001	Linear
Species/latitude	37	63.2	−3.37 ± 2.08	0.07	n.s.	Linear
Habitat/log area	37	1.13	6.59 ± 1.66	0.31	< 0.001	Linear
Habitat/latitude	37	4.19	−0.143 ± 0.194	0.02	n.s.	Linear
Species/log area/habitat	37	3.22	Area = 8.92 ± 1.36	0.74	< 0.0001 (t = 6.52)	Multiple
			Habitat = 2.97 ± 1.16		= 0.01 (t = 2.57)	
With wet forest						
Log species/log area	12	1.38	0.194 ± 0.027	0.83	< 0.0001	Linear
Without wet forest						
Log species/log area	24	1.33	$0.207x$ ± 0.037	0.77	< 0.0001	Polynomial
			$0.135x^2$ ± 0.04			

There was a highly significant relationship between species richness and habitat diversity when islands with a narrow range of areas were compared. The regression equation describing this relationship is: $y = 11.4 + 6.24x$, $R^2 = 0.95$, $n = 7$, $P < 0.0001$.

Species richness was significantly related to the presence of wet forest type for both habitat diversity levels 2 and 3 (habitat diversity level 2: Wilcoxon one-tailed test: $P = 0.05$. Habitat diversity level 3: Wilcoxon one-tailed test, $z = 2.54$, $P = 0.005$).

When the islands with and without wet forests were analysed, the slope of the regression between log species/log area reached an asymptote for islands without wet forests whereas it was linear for islands with wet forests (Table 3, Fig. 3). The majority of islands without wet forests are located below the regression line describing islands with wet forests indicating lower species richness on islands without wet forests (Fig. 3).

Five of the nine rare species (see Davidar *et al.*, 1996 for details) were predominantly wet forest dwelling, three preferred deciduous forests and one was a moist deciduous forest species. None had generalized habitat preferences. None of these were recorded on islands < 1 km^2 in area (Table 5).

Table 4 Mean number of forest bird species on islands of particular size categories in the North, Middle and South Andaman groups

Island size (km^2)	Mean number of species (n) North Andaman	Middle Andaman	South Andaman
< 0.1	6.6 (3)	–*	7.5 (2)
0.1–0.99	15 (9)	17 (3)	17.6 (5)
1–9.99	19 (3)	24 (3)	33 (3)
10–15	19 (2)	35.7 (4)	37 (1)

*No islands.

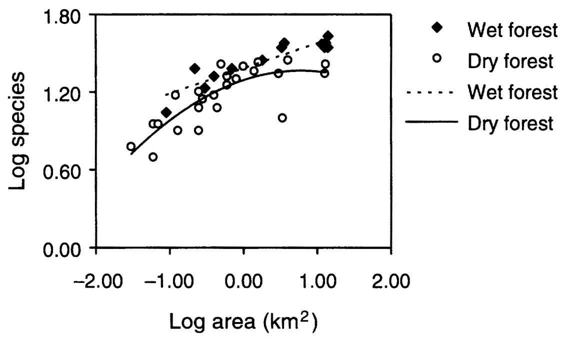

Figure 3 Species–area relationship of islands with and without wet forests. Islands with wet forests: $y = 1.38 + 0.194x$, $R^2 = 0.83$. Islands with dry forests: $y = 1.32 + 0.206x - 0.135x^2$, $R^2 = 0.77$.

Table 5 Habitat preferences of rare forest bird species and minimum size of islands on which recorded

Species	Status rank*	Habitat preferences†	Minimum island size on which recorded (km^2)
Coracina striata	1	Evergreen	116
Oriolus xanthornus	1	Moist deciduous	92
Chalcites xanthorhynchus	1	Evergreen	14
Terpsiphone paradisi	1	Deciduous	3.6
Dendrocitta bayleyi	2	Evergreen	3.6
Columba palumboides	2	Evergreen	1.8
Pycnonotus atriceps	2	Deciduous	1
Copsychus malabaricus	2	Deciduous	3.6
Aviceda leuphotes	2	Evergreen	1

*From Davidar *et al.* (1996).
†From Ali & Ripley (1987), Yoganand & Davidar (2000).

DISCUSSION

Species–area relationships

Statistical models

For all the islands surveyed, the exponential model between species and log area gave a better fit to the data than the power function. This is probably because of the 5-fold difference in area between the smallest and largest islands sampled, whereas the range of bird species was not large enough. As Connor & McCoy (1979) have suggested, the best fit model between species and area can only be determined empirically. In our case the data did not fit Preston's (1960, 1962) assumptions of true isolates and large species number (50–100). Many of the islands in our survey were in close proximity to each other making distance effects negligible, and the number of species included in the survey was less than 50. Thus, because Preston's (1960, 1962) assumptions were not met in our study (Connor & McCoy, 1979), we empirically determined the best fit model.

Habitat types, latitude and island size

The forest types in the Andamans change across the latitudinal gradient and with island size and were significantly nested across all island groups in the Andamans (Davidar *et al.*, in press). The littoral forest was the most common across all island groups and sizes. Wet forests were the least frequent and their distribution was significantly related to latitude and to island size. The proportion of islands with wet forests increased from the north to the south following the north–south rainfall gradient (Ellis, 1989), and were more common on larger islands (Davidar *et al.*, in press). Habitat diversity was significantly related to island area. Therefore both habitat diversity and the presence of wet forests are dependent on island area.

Determinants of species richness

Island size and habitat diversity significantly influenced species richness of forest birds in all the analyses conducted, although distance did not have an effect. The importance of island size and habitat diversity in influencing species richness was supported by analyses within island groups and for smaller islands as well.

There was also a significant effect of latitude on species richness. This is evident when the North Andaman group is compared with the Middle and South Andamans. Large and mid-sized islands in the North Andamans supported fewer species than islands of similar area in the Middle and South Andamans. The species/area slopes for the Middle and South Andamans indicated that species accumulate more rapidly with island size in these island groups. The intercept values across all island groups were similar, suggesting negligible latitudinal effects when only small islands are considered. This is probably because small islands host mostly widespread generalist species (Davidar *et al.*, in press).

Although area was very important in influencing species richness, the underlying habitat related parameters control the processes at a micro-level. When the effect of area was controlled, habitat diversity significantly influenced species richness. Similarly, when islands with similar levels of habitat diversity were compared, area was significantly related to species richness. Therefore both these parameters appear to be important determinants of species richness. The habitat diversity measure masks the importance of particular habitat types on species richness.

Effect of habitat type

When the relationships between species and area on islands with and without wet forests were analysed, the results showed that islands without wet forests species richness saturated on mid-sized islands, whereas it continued to increase on islands with wet forests. When islands of similar sizes with the same level of habitat diversity were compared, wet forests are significantly associated with increased species richness of forest birds on islands. The higher levels of species richness in the Middle and South Andamans are probably related to the presence of wet forests on smaller islands. In North Andamans, wet forests are confined to the large North Andaman island. Wet forests in the Andamans are probably reservoirs of many habitat specialists (Devy *et al.*, 1998; Yoganand & Davidar, 2000). Butterfly distributions in the Andamans are also strongly influenced by wet forests (Devy *et al.*, 1998).

The importance of wet forests for forest birds might be related to the biogeographical history of the Andamans and also because wet forests are species rich ecosystems. The Andaman biota have strong affinities with that of the Malay peninsula where wet forests are the predominant vegetation type (Ripley & Beehler, 1989; Whitmore, 1990). Therefore wet forests are probably the primary habitat for many species (Devy *et al.*, 1998; Yoganand & Davidar, 2000).

Boecklen (1986) shows that habitat heterogeneity increases the rate of species accumulation in forest birds, thereby suggesting that several reserves with more habitats would more effectively conserve biodiversity than a single large reserve. Our study shows that habitat type can significantly influence species richness. Therefore certain habitats which maintain the biodiversity at a regional scale can be called 'keystone habitats'. If the distribution of these keystone habitats is correlated with island size, which is the case in our study, then conserving several small islands would not be as efficient as conserving a large island which includes keystone habitat types.

Habitat preferences of birds

Analyses of the habitat preferences of 30 of these forest birds indicated that approximately half of these preferred wet forests and the rest deciduous forests. However these habitat preferences did not correspond with the overall distribution of these species within the Andamans (Yoganand & Davidar, 2000), i.e. species with restricted distributions were not specialists of wet forests. However the habitat preferences of only common species were analysed in this study, when rare species (of status 1–2, see Davidar *et al.*, 1996) were considered, it was seen that five of the nine species preferred wet forests. Probably these five species, which are also restricted to the larger islands (Table 4) make a significant difference in species richness across island groups and sizes. These rare species also indicate that wet forests occurring on the large islands are important reservoirs for Andaman biodiversity and should be protected on a priority basis.

Because of the close proximity and contiguity of the large islands and the archipelagoes in the Andamans, there is more uniformity in the species distributional patterns (Davidar *et al.*, 1996). Local races are not evident. The only exception to this pattern is the Narcondam Hornbill (*A. narcondami*) which is found on a single, relatively more isolated island. This is in contrast to the pattern recorded in the Nicobars where the islands are more scattered and isolated (Sankaran, 1997). The Little Andaman island which is a large, isolated island also could contribute to geographical isolation and speciation, and there are indications that this is so with regard to butterflies (Devy *et al.*, 1998).

CONCLUSIONS

This study indicates that whilst area and habitat diversity are equally influential in determining species richness on islands, the role of specific habitats needs to be explored further. These 'keystone' habitats which maintain regional biodiversity need to be identified and protected on a priority basis for the conservation of species and for the management of tropical biodiversity.

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REFERENCES

Ali, S. & Ripley, S.D. (1987) *Handbook of the birds of India and Pakistan*. Compact 2nd edn. Oxford University Press, Delhi.

Anonymous (1989) *Handbook on Andamans district*. Andaman and Nicobar Administration, State Statistical Bureau, Govt. Press, Port Blair.

Boecklen, W.J. (1986) Effects of habitat heterogeneity on the species–area relationships of forest birds. *Journal of Biogeography*, **13**, 59–68.

Boecklen, W.J. & Gotelli, N.J. (1984) Island biogeographic theory and conservation practice: species–area or specious–area relationships. *Biology Conservation*, **29**, 63–80.

Champion, H.G. & Seth, S.K. (1968) *A revised survey of the forest types of India*. Government of India Press, Delhi.

Connor, E.F. & McCoy, E.D. (1979) The statistics and biology of the species–area relationship. *American Naturalist*, **113**, 791–833.

Davidar, P., Soubadra Devy, M., Yoganand, T.R.K. & Ganesh, T. (1995) Reserve size and implications for the conservation of biodiversity in the Andaman islands. *Measuring and monitoring biodiversity in tropical and temperate forests* (eds T.J.B. Boyle and B. Boontawee), pp. 287–301. CIFOR, Jakarta.

Davidar, P., Yoganand, T.R.K., Ganesh, T. & Joshi, N. (1996) An assessment of common and rare forest bird species of the Andaman islands. *Forktail*, **12**, 135–142.

Davidar, P., Yoganand, K., Ganesh, T. & Soubadra Devy, M. Distribution of forest birds and butterflies in the Andaman islands, Bay of Bengal: nested patterns and processes. *Ecography*, in press.

Devy, M.S., Ganesh, T. & Davidar, P. (1998) Patterns of butterfly distribution in the Andaman islands: Implications for conservation. *Acta Oecologica*, **19**, 527–534.

Ellis, J.L. (1989) *Project document of North Andaman biosphere reserve in Andamans*. Botanical Survey of India, Port Blair.

Gaston, K.J. (1994) *Rarity*. Chapman & Hall, London.

Gilbert, F.S. (1980) The equilibrium theory of island biogeography: fact or fiction. *Journal of Biogeography*, **7**, 209–235.

Higgs, A.J. (1981) Island biogeographic theory and nature reserve design. *Journal of Biogeography*, **9**, 421–435.

King, B., Woodcock, M. & Dickinson, E.C. (1975) *Collins field guide to the birds of South-East Asia*. The Stephen Greene Press, Lexington, MA, USA.

Kohn, D.D. & Walsh, D.M. (1994) Plant species richness – the effect of island size and habitat diversity. *Journal of Ecology*, **82**, 367–377.

MacArthur, R.H. & Wilson, E.O. (1967) *The theory of island biogeography*. Princeton University Press, Englewood Cliffs, NJ, USA.

Preston, F.W. (1960) Time and space and the variation of species. *Ecology*, **41**, 611–627.

Preston, F.W. (1962) The canonical distribution of commonness and rarity. *Ecology*, **43**, 410–432.

Ripley, S.D. & Beehler, B.M. (1989) Ornithogeographic affinities of the Andaman and Nicobar islands. *Journal of Biogeography*, **16**, 323–332.

Sankaran, R. (1997) Developing a protected area network in the Nicobar islands: the perspective of the endemic avifauna. *Biodiversity and Conservation*, **6**, 797–815.

Siegel, S. & Castellan, N.J. (1989) *Non parametric statistics for the behavioural sciences*, 2nd printing. McGraw-Hill, New York.

Simberloff, D. (1976) Experimental zoogeography of islands: effects of island size. *Ecology*, **57**, 629–648.

Simberloff, D. & Abele, L.G. (1976) Island biogeographic theory and conservation practice. *Science*, **191**, 285–286.

Sokal, R.R. & Rohlf, F.J. (1981) *Biometry*, 2nd edn. Freeman, New York.

Welter-Schultes, F.W. & Williams, M.R. (1999) History, island area and habitat availability determine land snail species richness of Aegean islands. *Journal of Biogeography*, **26**, 239–249.

Whitmore, T.C. (1990) *An introduction to tropical rain forests*. Clarendon Press, Oxford.

Williams, C.B. (1964) *Patterns in the balance of nature*. Academic Press, London.

Wilson, E.O. & Willis, E.O. (1975) Applied biogeography. *Ecology and evolution of communities* (eds M.L. Cody and J.M. Diamond). Harvard and Belknap, Cambridge, MA, USA.

Yoganand, K. & Davidar, P. (2000) Habitat preferences and distributional status of some forest birds in Andaman islands. *Journal of the Bombay Natural History Society*, **97**, 375–380.

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Appendix 1 List of bird species and number of islands on which recorded

Bird species surveyed	Number of islands
Oriolus xanthornus	3
Chalcites xanthorhynchus	3
Coracina striata	3
Terpsiphone paradisi	3
Dendrocitta bayleyi	7
Aviceda leuphotes	8
Accipter virgatus	8
Columba palumboides	9
Pycnonotus atriceps	9
Copsychus malabaricus	10
Cuculus micropterus	11
Spilornis cheela	12
Spizaetus cirrhatus	13
Eurystomus orientalis	14
Eudynamus scolopacea	14
Macropygia rufipennis	15
Pericrocotus flammeus	16
Dryocopus javensis	16
Dicrurus andamanensis	16
Gracula religiosa	17
Zoothera citrina	17
Spilornis elgini	17
Psittacula alexandri	18
Chalcophaps indica	19
Dicaeum concolor	19
Coracina novaehollandiae	19
Treron pompadora	20
Psittacula eupatria	20
Artamus leucorhynchus	20
Aplonis panayensis	20
Sturnus erythropygius	21
Merops leschenaultii	21
Psittacula longicauda	22
Picoides macei	22
Centropus andamanensis	22
Zosterops palpebrosa	23
Hypothymis azurea	23
Ducula aenea	24
Pachycephala grisola	25
Pericrocotus cinnamomeus	25
Dicrurus paradiseus	25
Irena puella	26
Copsychus saularis	26
Oriolus chinensis	27
Pycnonotus jocosus	28
Nectarinia jugularis	28

Appendix 2 List of islands, habitat diversity and species richness of forest birds

	Islands surveyed		
Island	Area (km^2)	Number of species	Number of habitats
North Andamans			
North Andaman	1128	43	5
Landfall	13	26	2
Sound	12.7	22	2
Paget	4	28	2
North Reef	3.4	10	1
East	3	22	3
Point	0.8	20	2
Reef	0.6	21	1
Delgarno	0.5	26	2
Excelsior	0.4	17	2
Ross	0.3	17	3
Pocock	0.25	16	2
Aves	0.25	8	2
Turtle	0.13	8	2
Curlew	0.07	9	2
Temple	0.06	9	3
Egg	0.06	5	3
Middle Andamans and Baratang			
Baratang	230	44	5
Havelock	92	45	5
John Lawrence	35	43	5
Peel	23	34	4
Long	14	43	5
Wilson	14	35	4
North Passage	13	38	4
Neil	12.6	35	4
Nicholson	1.8	28	2
Inglis	1.4	23	2
Guitar	1	25	2
Hugh Rose	0.6	18	2
Middle Button	0.4	21	2
North Button	0.25	12	2
South Andamans			
South Andaman	1348	47	5
Rutland	116	44	5
Tarmugli	11.5	37	4
Alexandria	3.6	38	3
Redskin	3.3	35	3
North Cinque	1.6	27	2
Malay	0.7	24	3
Twins	0.44	12	2
Ross	0.28	14	1
Snob	0.22	24	2
Jolly Buoy	0.12	15	2
Chester	0.09	11	2
Grub	0.03	6	1
Little Andaman	675	41	5

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